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AD NUMBER
AD398391
CLASSIFICATION CHANGES
TO: unclassified
FROM: confidential
LIMITATION CHANGES
TO: Approved for public release, distribution unlimited
FROM: Distribution authorized to DoD only; Test and Evaluation; 28 OCT 1948. Other requests shall be referred to Picatinny Arsenal, Dover, NJ. Pre-dates formal DoD distribution statements. Treat as DoD only.
AUTHORITY
31 Oct 1960, DoDD 5200.10; ARRADCOM ltr dtd 13 Feb 1980

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PICATINNY ARSENAL

TECHNICAL DIVISION

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TECHNICAL REPORT

SUBJECT: MATERIALS FOR NON-METALLIC ROCKET LAUNCHING TUBES

PICATINNY ARSENAL
TECHNICAL INFORMATION SECTION

PROJECT No. TU2-3002A **REPORT No.** 1

PREPARED BY G.R. Rugger **DATE** 28 October 1948

SERIAL No. 1704

COPY NO. 18

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MATERIALS FOR NON-METALLIC ROCKET LAUNCHING TUBES

PROJECT No. TU2-3002A

Report No. 1

Picatinny Arsenal Technical Report No. 1704

28 October 1948

Prepared by:

G.R. Rugger
Chemist

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PICATINNY ARSENAL

Authorization: Ordnance Research and Development Division, ORDTU

Project No: TU2-3002A

Priority Designation: 2B

Project Title: Design, Develop, and Furnish 25 Non-Metallic or Composite Rocket Launching Tubes

Object: To develop a plastic or plastic/metal composite rocket launching tube which would reduce or eliminate heating.

Summary: A composite launcher tube consisting of an asbestos fabric/phenol-formaldehyde laminated liner inside an aluminum supporting tube and fitted with a protective ring at the front and a supporting ring at the back has passed all preliminary firing tests and appears satisfactory for further work in the development of a multiple tube launcher. Unsupported laminated tubes all failed either through bursting or through delamination when used to launch spin-stabilized rockets previously warmed to 49°C (120°F). Evidence to date indicates that a satisfactory unsupported plastic tube may be obtainable by combining a construction on the inside which has good delamination resistance with a construction on the outside which has good bursting resistance.

Conclusions: Preliminary work had shown that plastic tubes do not become hot from rocket firing as metal tubes do. It has now been shown further that a composite launcher tube consisting of a plastic liner in an aluminum outer tube combines resistance to heat with satisfactory resistance to bursting and other forms of mechanical destruction. It is proposed that this composite tube be investigated in an experimental multiple tube launcher if one is built in the near future and that, simultaneously, work be continued with the objective of providing an all plastic launcher tube to be used ultimately in place of the composite tube.

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Recommendations:

It is recommended that a composite tube consisting of an asbestos base laminated liner with an aluminum outer tube be used for any multiple tube launcher required in the immediate future.

It is recommended that work be continued with the objective of providing an all plastic tube to be used ultimately in place of the composite tube.

INTRODUCTION:

1. A major cause of dissatisfaction with multiple rocket launchers as designed and used in World War II was the tendency of the steel tubes to overheat. This was undesirable because (a) if rockets were allowed to remain in hot launching tubes there might be leakage of molten TNT as the heat was transferred to the rocket, (b) as the propelling charge was heated, the ballistics of the rocket would be changed, and (c) the reloading of the launcher was less rapid when personnel had to avoid touching hot areas. Accordingly, work was initiated on this project in an effort to provide tubes that did not become hot upon repeated firings.

2. Preliminary investigations had shown (Ref A) that plastic tubes were superior to metal tubes because the plastic tubes did not become as hot under the influence of repeated but intermittent blasts of rocket gases. It was further shown that a high pressure thermosetting laminated tube should be superior to a low pressure thermosetting laminated tube or low or high pressure thermoplastic laminated tube in resistance to delamination during firing.

RESULTS:

3. A metal/plastic composite tube consisting of an inner plastic liner with an outer aluminum shell reached maximum temperatures of 92°C, 71°C, and 74°C (198°F, 160°F, and 166°F) on the outside at the back, middle, and front, respectively during the firing of 100 rockets. (Appendix A, Rocket Firings 18 and 20). Maximum temperatures measured on the inside of the tube were 66°C and 51°C (150°F and 123°F) at the back and front, respectively. By comparison, standard steel launching tubes reach temperatures much too hot to permit touching after two firings (Ref A).

4. The composite tube described in the preceding paragraph did not burst even under relatively unfavorable conditions. The 100 rockets fired consisted of 10 rockets at 49°C (120°F), followed by 85 rockets at 25°C (77°F), followed by a final 5 rockets at 49°C (120°F). The tube was cooled to -40°C (-40°F) before firing the first rocket. After the tube had been weakened as far as could be expected by erosion from the firing of the first 95 rounds, a final five rounds were fired with the rockets heated to 49°C (120°F) before firing. (Appendix A, Rocket Firings 18 and 20).

5. The molded asbestos base liner in the composite plastic/metal tubes showed no tendency toward delamination at the front end of the tube or at points where holes had been cut through the tube, exposing a face of the laminate perpendicular to the blast of the rocket gases. Delamination at the front edge was eliminated by the use of a beveled edge which was then

covered with a metal protective ring. Rings screwed to the outside of the metal tube presented an unbroken surface to the rocket gases and were satisfactory, but rings screwed to the inside of the outer tube presented a crack into which the gases could enter and flare out the tubes (Appendix A, Rocket Firing 17). As a precaution, thermosetting sealing materials were used to fill the small cracks between the face of the laminate and the protective rings. No sealing material was used between the laminated tube and the metal tube.

6. On the composite tube erosion at the rear end varied from 0.035" to 0.065" while at the front end, the loss of laminate due to erosion was only 0.005" to 0.010" (Appendix A, Rocket Firings 18 and 20). The effects of erosion were measured only in the case of the composite tube since the other tubes either broke or were severely delaminated before erosion became noticeable.

7. Flammability resistance of the composite tube was very good, no damage to either component being visible.

8. Glass fabric base tubes did not burst when rockets previously heated to 49°C (120°F) were fired from them. Tubes prepared from fabric woven with equal strength in both directions were sufficiently resistant to bursting with wall thicknesses of 0.150", while tubes made with glass fabric having ten times the strength circumferentially that it had longitudinally resisted bursting when wall thicknesses were as low as 0.100". However, all glass fabric base tubes delaminated seriously during the firing of one to five rockets (Appendix A, Rocket Firings 7, 8, 11, 12, 15, 16, and 19).

9. Asbestos fabric base tubes having a wall thickness of 0.125" (1/8") and no external shell did not burst when rockets at a temperature of approx. 25°C (77°F) were fired. However, these tubes did burst when rockets were used that had been heated previously to 49°C (120°F). Tubes of the same construction except for 0.250" (1/4") walls failed similarly (Appendix A, Rocket Firings 3, 4, and 5).

10. Cotton fabric base tubes burst upon firing rockets at approximately 25°C (77°F). (Appendix A, Rocket Firing 6). Paper base laminated tubes proved to be the weakest in bursting resistance of any of the constructions investigated. (Appendix A, Rocket Firing 13).

11. Both melamine-formaldehyde and phenol-formaldehyde high pressure resins proved satisfactory in flame resistance. In some cases, one or the other class of resins blistered but the variations between the same resins from different manufacturers was greater than it was between the two types of resins. (Appendix A, Rocket Firings 4, 5, 6, 14, and 17). Some of the low or contact pressure polyester resins proved to be inflammable (Appendix A, Rocket Firings 16 and 19).

DISCUSSION OF RESULTS:

12. The first phase of this investigation has been directed toward finding an acceptable tube which could be used immediately if it is so desired. It is intended that the search for a better, cheaper, and more available tube will be continued.

13. An indication of what would probably be the best material was given by the preliminary static testing (Ref A). This test indicated that a high pressure thermosetting laminate would probably be most suitable for this particular use. Low pressure thermosetting laminates showed more tendency to delaminate than did the high pressure thermosetting laminates. Extruded thermoplastic tubes were excluded from consideration because the preparation of such tubes in the desired size is extremely difficult. Thermoplastic laminates were excluded because of the inherent tendency for thermoplastics to soften with heat. Glass, asbestos, cotton, and paper base tubes were all included because the previous test gave no indication of the bursting strength required nor of the effect produced by the rocket's scraping on the tube walls.

14. The combination asbestos base/aluminum tube was found to be very effective in reducing heat absorption and heat transfer. Whereas the temperatures reached a maximum of 92°C (198°F) after firing twelve rounds at the rate of one every 1-1/3 minutes, previous tests showed that steel tubes underwent temperature rises of 149°C (300°F) after the firing of three salvos (Ref B). The higher temperatures measured on the outside of the composite tube are apparently due both to the fact that a metal surface is exposed on the outside and to the fact that the experimental firing conditions permitted the flames from the departing rocket to impinge on the outside of the tube as well as on the inside.

15. Conditions of firing were intentionally made extreme with respect to pressure development by the firing of ten heated rockets (49°C (120°F)) from a tube initially cooled to -40°C (-40°F) (Appendix A, Rocket Firing 20). Since plastics in general have lowest impact strengths at low temperatures and since rockets produce highest pressures when fired at elevated temperatures (Ref C), this combination of cold launching tube and hot rocket produced the greatest shock when the tube was least resistant to shock. However, no failure was experienced. The last five rockets were also heated prior to firing. This gave maximum shock to the tube after maximum erosion had occurred.

16. Delamination resistance of the molded asbestos tube proved to be excellent. Even when fracture of the rear supporting ring allowed the inner tube to slide back away from the front protective ring and thus expose the front edge of the tube (Appendix A, Rocket Firing 18), four heated rockets were fired without delamination of the plastic. This also demonstrated

definitely the need for a back supporting ring to prevent such slippage. The friction of the gases flowing down the tube before the rocket leaves the launcher causes about one thousand pounds reaction on the launcher tube (Ref D). In a composite tube this represents a one thousand pound load tending to force the plastic liner backward out of the aluminum tube. This figure is for firings of the M8 fin stabilized rocket but there is no reason for believing this figure would be less with a spin stabilized rocket.

17. The erosion observed was probably insufficient to affect ballistics seriously. While, at the rear end, the given limits of 0.010" per 100 rounds was exceeded, the front two-thirds of the tube did not show erosion in excess of the limits and thus should have guided the rockets accurately.

18. Whether or not a sealing compound is needed for the protective rings was not proven but it was definitely shown that no sealer is needed between the inner and outer tubes.

19. Glass fabric base laminates were shown to have exceptional bursting resistance. The heat transfer was greater than for asbestos but still was very much less than it would be for metal. These tubes all showed poor resistance to delamination and this weakness was aggravated by breaks in the surface such as those required by holes for rivets, firing fingers, etc. This delamination prevented taking any data on erosion.

20. Although asbestos base tubes had sufficient bursting resistance when the rockets used were at ambient temperatures, rockets heated to 49°C (120°F) burst all the asbestos tubes tested without a supporting outer tube. Cotton and paper base tubes also showed a lack of bursting resistance.

EXPERIMENTAL PROCEDURE:

21. All firings after the first two were made from a mount attached to the barrel of a 75 mm. cannon (M-33919, M-33920, M-33921, and M-33922). Details of the mount are shown in these photos This arrangement was made because the cannon provided the required stability and was at the same time mobile. A concrete block would have made a mount that was even more stable but this would have prevented the use of the tunnel for other tests. All firings were made at $0 \neq 5^{\circ}$ elevation since this condition would provide the most severe erosion from scraping and would also allow the maximum blast effect on the inside of the tube. The tube was sighted by means of a cardboard disk with a hole punched in the center at the rear of the tube and crosswires on the front end. The elevating and transversing mechanism of the cannon was used to change the aim of the launcher. Firings were made through a wooden tunnel into a pile of sand and dirt. This is the standard tunnel for bullet impact and similar tests.

22. Erosion measurements were made with inside micrometers. Temperatures were taken with a "Wheelco" portable pyrometer with an iron/constantan thermocouple. The dial read directly in °F. A portable barricade about 25 feet from the mount sheltered personnel who fired the rockets by means of a standard blasting generator. This distance was small enough that the temperature readings could be taken within 30 seconds after the rocket was fired.

MATERIALS USED:

23. The rockets used were 4.5" M17 and M17E1 rockets assembled by the Loading Branch at Picatinny Arsenal. It was desirable to use a spin stabilized rocket since the trend in rockets for ground force use is toward such rockets. These were inert loaded and were constructed as shown in drawing 82-16-16, Rev. 5, with a closing plug in place of a fuze and the lead wires hanging out through a nozzle for ease in firing. The propellant was 4.81 ± .01 pounds of standard double base rocket propellant.

24. The tubes used in each firing are described in Appendix A.

REFERENCES:

Ref A - Picatinny Arsenal Chemical Laboratory Report No. 119227, 4 November 1946, "Non-Metallic Rocket Launching Tubes".

Ref B - Aberdeen Proving Ground, "First Report of Development of Launchers, Rocket, Multiple, 4.5" T108 and T108E1", Project 6552, 30 August 1946.

Ref C - Aberdeen Proving Ground, "Second Report on Research on Blast Reaction on Launchers, Rocket, Multiple, 4.5"", 53rd Report on Ordnance Program 5191, 29 May 1945.

Ref D - Aberdeen Proving Ground, "First Report on Blast Reaction on Launchers, Rocket, Multiple, 4.5" and 35th Report under Ordnance Program No. 5191", 11 November 1944.

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APPENDIX A

ROCKET FIRINGS 1 THROUGH 22

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ROCKET FIRING #22

No. of Rockets Fired: Two

Rockets Used: M17, 4.5" practice rockets as furnished by the Loading Branch. These were heated to 49°C (120°F) by overnight storage in an air oven.

Launcher Tube Used: This was a molded glass base tube with melamine resin. It was purchased from National Vulcanized Fibre Co. It had protective rings fitted at Picatinny Arsenal and these were held in place with four set screws. It was called Grade FG-128-M. The dimensions were 4-9/16" I.D. and 5" O.D.

Conditions of Firing: The firings were conducted under the same conditions as previous firings.

Results of Firings:

Round 1 - Small area about 2½ x 3" at the front edge where the tube was not completely protected by the ring showed wear. Otherwise there was no damage.

Round 2 - The center section split along the seams formed by molding. The front 14" and the back 6" were not split. What delamination there was was probably caused by the splitting rather than being true delamination. The resin appeared to be cooked more than is usual for melamine resins.

Conclusions: Although they were not visible, there may have been small cracks caused by the firing of the first round. Otherwise it is difficult to see why the first round should result in so little damage and the second one so much. The fact that the front and back portions were not split may have been due to the fact that the clamps were holding the tube together. The Al rings might also have had a small influence in this direction.

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ROCKET FIRING #21 17 Dec. 1947

No. of Rockets Fired: Two (2)

Rockets Used: M17, 4.5" practice rockets as prepared by the Loading Branch. The rockets were heated to 49°C (120°F) by overnight storage in an air oven.

Launcher Tube Used: This was a glass base rolled tube furnished by Westinghouse Electric Corp. Information from Mr. Bastian was only that this was a "high resin content", the amount of resin not being known to him. This was fitted with aluminum protective rings by Picatinny Arsenal. These rings were attached to the tube with four set screws each. The Fiberglas used appeared to have a finer weave than usual.

Condition of Firing: Same as previous firings.

Results of Firing:

Round 1 - Erosion at the rear end looked as though two or three layers of cloth were removed for a distance of about 6" from the rear. This showed up over about 1/2 the circumferential area. The missing cloth came off in patches rather than in sheets. There were no holes or other starting causes here.

Round 2 - Erosion proceeded with the whole inside area of the tube being affected for a distance of 12-14 inches from the rear. The back ring was blown off. One piece of cloth $1\frac{1}{2}$ x 2 " was gone about $1\frac{1}{2}$" from the front edge. Also at the front end of the tube there were several places (small) where it looked as though just one layer of cloth had been torn off. There was no delamination at the screw holes.

Conclusions: There was no visible reason for the wear to come where it did. When loading the launcher, the rocket seemed to fit snugger than usual, especially on the second round. The patch mentioned as being missing from the front of the tube looked very much as though it had been scraped by a metal rather than by a gas.

ROCKET FIRING #20 (Contd)

General - The firing finger holes did not cause the tube to break out where it was not supported by the Al tube. This had happened on the previous test. The threads by which the protective rings were fastened showed some deterioration - it is not known whether the blast effects were the cause of this or if the damage was done in removing the rings from the now out-of-round tubes. In any case, the damage was of a minor nature and did not interfere with the test in any way. The tube assembly remained in place on the mount, it did not slide back after being securely fastened after the first 10 rounds.

Conclusions:

With a cold tube (exact temperature unknown but it had been at -40° before taking up the hill to mount) no trouble was experienced due either to unequal expansions or brittleness of the inner tube.

With the tube as used, erosion is greater than the limits set up by the OCO (limit of 0.010" in 100 rounds) at the back while the amount at the front is just about the amount allowed.

The longest, fastest, firing was 12 rounds in 16 minutes, or an average of 1-1/3 minutes per round. On this run the outside temperatures reached a maximum of 198°, 160°, and 166°F for back, middle, and front, respectively while the inside temperatures reached 157° in back and 127°F in front. These inside temperatures were measured after the 7th round of this series. At the end of the 12 rounds, these temperatures had fallen to 152 and 123°F. While these temperatures were higher than those previously obtained, they are still not excessive and would be greatly lowered in a multiple launcher where a maximum rate of fire is once in three minutes.

ROCKET FIRING #20 (Contd)

	Clamped Down Portion of Tube	
	Back Edge	Front Edge
Increase		
Smallest	0.043	0.006
Largest	0.024	0.003
After 100 rounds		
Smallest	4.588	4.533
Largest	4.641	4.568
Increase		
Smallest	0.030	0.004
Largest	0.018	0.002
Total Increase		
Smallest	0.011	0.010
Largest	0.042	0.005

These data indicate that some of the measurements must be in error. However, it shows that the erosion is greater than that allowed at the back while the front end would be acceptable.

Front Edge - The front edge shows resin burnt away from the asbestos for a maximum of $\frac{1}{2}$" and in any case, the loss is not of importance. The ring is about 1/32" away from the tube but this did not cause any trouble. On the 98th shot, the front aluminum ring looked as though it had a small crack but this could not be found after firings were completed. This was only 1" long and by this time the ring had withstood 96 + 98 or 194 rounds. Otherwise, the ring looked perfectly good. There was a small chip in the tube about 3/4" from the front edge where there must have been a void of asbestos; this was noticed after the 10th round and did not get any worse so that it caused no trouble.

Back Edge - The back edge was eroded away but it was still 1/16" thick in most places. There were three small chips taken from the extreme back edge - these were about 3/4" long and 1/8 to 3/16" deep. They caused no trouble. The lip of the back Al ring was worn down but this had been designed so that it came down to a thin edge and so this was expected. It was not worn enough after 100 shots to allow the tube to slip back and so was not of importance.

ROCKET FIRING #20 (Contd)

Measurements after firing 75 rockets (10 of them at 120°F). Tube clamped into position on mount.

Front edge of tube	Horizontal 4.529	Vertical 4.566
Back edge of tube	Horizontal 4.618	Vertical 4.623

Measurements after firing 100 rockets (15 of them at 120°F). Tube clamped into position on mount.

Front edge of tube	Horizontal 4.533	Vertical 4.568
Back edge of tube	Horizontal 4.683	Vertical 4.631
		Horizontal 4.663 ½" from edge

Measurements after firing 100 rockets; tube unclamped from mount.

Back edge of tube	Smallest 4.588	Largest 4.641
3" from back edge	Smallest 4.568	Largest 4.595
6" from back edge	Smallest 4.555	Largest 4.583
Front edge of tube	Smallest 4.523	Largest 4.557
3" from front edge	Smallest 4.523	Largest 4.554
6" from front edge	Smallest 4.533	Largest 4.554
Front ring	Smallest 4.534	Largest 4.570

No fair comparison can be made between the measurements taken while the tube was clamped down as compared to when it was unclamped as there would be some distortion due to the clamping force. However, the following comparisons can be made.

Unclamped Portion of Tube	Before Firing		After Firing 100 Rds		Increase	
	Smallest	Largest	Smallest	Largest	Smallest	Largest
Front ring	4.525"	4.533"	4.534"	4.570"	.009"	.047"
Front edge of tube	4.512"	4.550"	4.523"	4.554"	.011"	.004"
Back edge of tube	4.553"	4.574"	4.588"	4.641"	.035"	.067"

	Clamped Down Portion of Tube	
	Back Edge	Front Edge
After 40 rounds		
Smallest	4.577	4.523
Largest	4.599	4.563
After 75 rounds		
Smallest	4.618	4.529
Largest	4.623	4.566

ROCKET FIRING #20 (Contd)

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Round	Time	Outside Temperatures Back	Middle	Front	Remarks
90	3:07	189	152	160	Inside temps. - 157°F, back; 127°F, front
91	3:09	187	158	162	
92	3:10	198	160	166	
93	3:12	174	150	156	
94	3:14	193	156	165	
95	3:15	195	159	166	Inside temps. - 152°F, back; 123°F, front. Small chips about 1/32 x 3/16 and 1/16 x 1/2 along back edges; twelve rounds in 16 minutes.
96	3:20	160	140	160	Rounds 96-100 at 120°F.
97	3:22	169	150	155	
98	3:23	180	152	146	Inside temps. - 149°F, back; 119°F, front; front ring shows slight crack about 1" long. Three rounds in 3 minutes.
99	3:28	159	140	135	
100	3:30	178	150	150	Inside temps.- 168°F, back; 112°F., front. From 12:45 to 3:30, average of one round every 3 mins. was maintained.

Results of Firing:

Erosion - Measurements before firing, tube not clamped to mount.

Back edge of tube	Smallest 4.553	Largest 4.574
Front edge of tube	Smallest 4.512	Largest 4.550
Front ring	Smallest 4.525	Largest 4.533

Measurements after 40 rockets had been fired (10 of them at 120°F). Tube clamped into position on mount.

Back edge of tube	Horizontal 4.577	Vertical 4.599
Front edge of tube	Horizontal 4.523	Vertical 4.563
Front ring	Horizontal 4.532	Vertical 4.565

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ROCKET FIRING #20 (Contd)

19 Nov. 1947

		Outside Temperatures			
Round	Time	Back	Middle	Front	Remarks
60	1:28	135	128	130	Inside temps. - 127°F, back; 100°F, front
61	1:30	150	128	145	Lost time looking for rocket still burning as it hit.
62	1:38	122	110	116	
63	1:40	133	119	122	
64	1:42	138	122	129	
65	1:45	130	115	129	Inside temps. - 119°F, back; 106°F, front
66	1:50	119	114	116	
67	1:52	130	113	122	
68	1:54	Loose connection - did not fire			
	1:55	129	112	122	Tore up tunnel some, including shearing pieces from 1/2" steel plate. Cleaned tunnel.
69	2:03	119	104	108	
70	2:05	122	112	112	
71	2:08	134	115	126	
72	2:10	141	122	132	
73	2:12	156	125	131	
74	2:15	145	130	130	
[illegible]	2:18	150	127	125	Inside temps. - 118°F, back; 105°F, front; I.D. measurement taken.
76	2:45	97	90	96	
77	2:46	117	103	110	
78	2:47	140	111	117	
79	2:49	156	124	136	
80	2:50	158	132	136	Inside temps. - 143°F, back; 110°F, front.
81	2:52	163	143	146	
82	2:53	166	136	145	
83	2:55	170	143	148	Inside temps. - 142°F, back; 123°F, front; 8 rounds in 10 minutes.
84	2:59	150	140	141	
85	3:00	168	142	146	
86	3:01	172	146	150	
87	3:03	190	156	152	
88	3:04	192	156	163	
89	3:06	192	152	158	

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ROCKET FIRING #20 (Contd)

13 Nov. 1947

Round	Time	Outside Temperatures Back	Middle	Front	Remarks
31	3:17	113	102	95	
32	3:25	112	95	98	
33	3:28	117	102	109	
34	3:30	119	104	109	
Inside temps.		93	97	88	
35	3:35	110	109	106	
36	3:38	119	111	116	
37	3:40	118	110	122	
38	3:43	125	114	118	
39	3:46	129	108	119	
40	3:48	122	113	111	Atmospheric temperature at firing site - 61°F.
Inside temps.		100	92	92	I.D. Measurement taken.
19 Nov. 1947					
41	11:19 AM	75		75	Before firing - tube + 35°F Inside temp. - back + 70°F
42	11:23	93	85	90	
43	11:26	92	95	90	
44	11:29	122	100	105	
45	11:31	120	109	111	Inside temps. - 93°F back, front 92°F.
46	12:45 PM	80	65	70	
47	1:00	85	70	70	Official temp. + 40°F.
48	1:03	95	85	91	
49	1:05	112	100	103	
50	1:07	125	105	109	Inside temp. - 113°F, back
51	1:09	132	110	118	
52	1:11	130	115	123	
53	1:13	137	116	120	
54	1:15	145	126	129	
55	1:16	149	129	132	Inside temps. - 129°F, back; front, 106°F; 9 rounds in 16 minutes.
56	1:20	130	118	123	
57	1:23	130	117	119	
58	1:25	144	121	129	
59	1:27	142	127	136	

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ROCKET FIRING #20 (Contd)

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Round	Time	Outside Temperatures Back	Middle	Front	Remarks
2	9:32	Tube still cool			Resin burned a little in back.
3	9:43	Tube still cool			
4	9:45	Tube barely warm			
5	9:52	Tube barely warm			
6	9:56	98	60	70	
7	9:59	95	65	70	Atmospheric Temperature at firing site 53°F; clear, slight wind.
8	10:02	115	112	105	Thin edge of back Al ring slightly curled.
9	10:05	120	115	105	98°F on inside at back.
10	10:10	109	95	105	
11	11:17		Cold		Small flaw in tube about 3/4" back of front edge.
12	11:19	90	84	70	
13	11:21				Inside temperatures - 105°F, back; 87°F, front.
14	11:23	120	100	113	Inside temperature - 97°F front
15	11:25	105	103	110	Inside temperature - 95°F front
16	11:29	106	100	110	Held up by persons on range.
17	11:33	104	96	107	Inside temperature - 96°F back
18	11:36	115	110	90	Inside temperature - 98°F back
19	11:38	116	90	115	Inside temperature - 91°F back, 83°F front.
20	11:42	115	113	114	Inside temperature - 93°F back, 90°F front.
21	2:51 PM	75	65	70	
22	2:53	88	75	80	
23	2:56	100	85	90	
24	2:58	100	75	80	
25	3:00	103	97	110	Inside temperature - 100°F back, 80°F front.
26	3:03	112	111	100	Official temperature 44°F.
27	3:05	117	90	105	
28	3:07	122	108	110	
29	3:10	119	100	109	
30	3:12	121	101	112	Inside temperature - 100°F back, 90°F front, 10 shots in 21 min.

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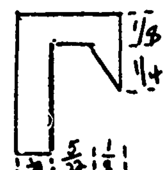
ROCKET FIRING # 20 13-19 Nov. 1947

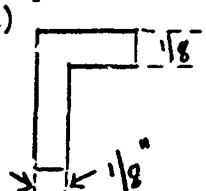
No. of Rockets Fired: 100

Rockets Used: The rockets used were from a new batch freshly prepared by Loading Branch. These were M17 rockets rather than M17E5. These differed from the M17E5 in that a booster tube was attached to the war head but this made no difference except in the volume available for gas expansion in themotor tube. These booster tubes were inert loaded. The first 10 and the last 5 had been heated to 120°F by overnight storage in a constant temperature oven. Only the last five rather than the last ten were heated due to lack of heating space and the desire to finish the test rather than delaying it another two days.

Launcher Tube Used: This was a composite tube and was just the same as the tube used for Rocket Firing #18 except for the rear aluminum protective ring which was made as follows: (A side view is shown).



In Rocket Firing #18 the rear protective ring was as shown: (A side view is shown)



The tube was cooled to -40°F by overnight storage.

Results of Firing:

13 Nov. 1947

Round	Time	Outside Temperatures Back	Middle	Back	Remarks
1	9:28	Tube still cold			All temperatures in °F. Rockets 1-10 heated to 120°F. Inner surface of tube blackened. Official 9:00 AM temperature was 40°F.

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ROCKET FIRING #19 2 October 1947

No. of Rockets Fired: 1

Rocket Used: An M-17, 4.5" practice rocket as prepared by Loading Branch. Rocket was heated to 49°C (120°F) by overnight storage.

Launcher Tube Used: The tube was one of U.S. Plywood's and was composed of "Fiberglas" 143-14 and a low pressure resin (probably "Selectron" 5016). It was 36" long, 4-9/16" I.D. with wall thickness of 0.100". It was fitted with Al rings front and back held in place by "Bakelite" XJ16320 in order to avoid holes on inner surface.

Condition of Firing: Same as on previous tests.

Results of Firing: The front protective ring was blown off. The inner surface was delaminated in single threads and small strips for 4" back from front edge. The outer surface had a tendency to delaminate. The rear portion of the tube caught fire from the blast. The ridge of "Bakelite" XJ16320 which was made by squeezing the ring on was burned away although enough was left to hold the ring on.

Conclusion: Any resin which catches fire is unsuitable for such an application.

It is very doubtful if a low pressure tube can be fabricated to give the desired delamination resistance.

This tube did not break but a weakness shown indicates it would have on the second rocket. It is very doubtful if such tubes as these will be of any value.

ROCKET FIRING #18 (Contd)

Conclusions: (Contd)

The fastest time achieved for a batch of 10 rockets was 22 minutes. If more speed is desired, the mounting may have to be put on a concrete block as the single spade on the 75 mm cannon allows the launcher to shift and it must be resighted each time in order to be safe.

The composite tube used was by far the best used to date.

ROCKET FIRING #18 (Contd)

Results of Firing (Contd):

Rear Edge - About 1" was broken from the rear edge of the inner tube all the way around. This had been worn down by erosion of the gases but not to too large an extent. The portion left (1" from original end of tube) still had a thickness of 0.096" as compared to the original 0.125". The main trouble caused by this was that as the tube was worn down more of the lip on the Al ring was exposed to the blast. This resulted in the lip being blown off and in turn, this allowed the inner tube to slide back within the outer tube. This lip had been machined slightly thin (about 0.100" rather than the 0.125" called for in the drawing.)

Conclusions:

Where bursting strength is taken care of by an outer Al tube, molded tubing is much superior to rolled tubing because of its delamination resistance.

Had this tube been 3/16" thick rather than 1/8", the extra 1/16" would have probably enabled the 101 shots to be fired. The use of rails may have lessened the erosion to the extent that the tube would have been successful. The avoidance of all holes in the outer tube is desirable. Where the use of these is unavoidable (i.e. for firing fingers) it might be possible to press an Al ring in to protect the edge of these holes. If necessary, a few rivets could join the two tubes at the front edge only, to help prevent the tube from sliding back in case the rear ring fails. By being fastened at the front edge only, these would not tend to tear the tubes due to unequal expansion and this idea is also favored by the fact that the wear here is very slight. At the rear end as the tube wore down the rivets would protrude from the inner surface and tend to grab the rocket or else give it a small guiding contact.

In production, the high cost of machining the two tubes to fit each other might be lowered by using a wire wrap rather than the Al tube.

The temperatures obtained were very satisfactory. The highest measured inside temperature was 130°F. at rear and 125°F at front. The highest outside temperatures obtained were 171, 150, and 145°F for back, middle, and front respectively. While no measurements of time vs. loss of heat were taken, these cooled down very rapidly. This compares with 300°F rise after three salvos with steel tubes.

ROCKET FIRING #18 (Contd)

2 Oct. 1947

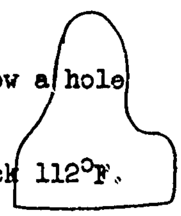
Round	Time	Outside Temperatures Back	Middle	Front	Remarks
89	1:27	116	99	101	3" section of rihg broken off.
90	1:30	138	108	110	Inner tube about 1/16" thick at rear edge.
91	1:32	136	109	119	Inner tube turned about ½" indicated by covering firing finger hole.
92	1:41	120	110	104	Rounds 92 through 96 were 120°F. Broke off all but 1" of rear ring.
93	1:44	125	108	113	Tube slid back ½" inside outer tube.
94	1:53	118	111	110	Tube moved back another 3/4", front edge undamaged.
95	1:56	124	118	120	Outer tube shifted back 3/4" for first time it had moved. Inner tube unchanged in position and damage.
96	2:05				Inner tube broken.

Results of Firing:

Front Edge - The inner tube was broken by gas which got between the two tubes. One third of the circumference remained all right, 1/3 was broken about one inch from the front edge, and the remaining 1/3 was broken out about 5 inches from front edge. The unbroken portion still was nearly the original thickness, with all damage due to burning out of resin. There was no delamination although this edge has been unprotected for the firing of four hot rockets. There were four 3/4" x 1/8" nicks in the tube from 4" to 10" from front edge. These did not go through to the metal, apparently being voids of asbestos and where there were pockets of resin. These were present during most of the firing and were no cause of trouble. The Al ring was undamaged.

ROCKET FIRING #18 (Contd)

1 Oct. 1947

Round	Time	Outside Temperatures Back	Middle	Front	Remarks
72	3:17	145	125	120	Inside tubes - Front 110°F, Back, 122°F.
73	3:21	149	125	132	
74	3:23	163	135	137	Three holes, $\frac{1}{4}$ x $1\frac{1}{2}$" at edge of rear Al ring.
75	3:26	160	136	136	
76	3:29	170	135	140	Piece of inner tube between round hole and long hole broke out.
77	3:31	170	138	145	Fired 10 shots in 24 mins. Inside tubes - Front, 118°F, Back, 121°F.
78	3:38	140	130	128	At this time, had three holes at edge of rear Al ring 3/16 x 2". One hole $\frac{1}{2}$ x $1\frac{1}{2}$" at right angle to long hole, front edge was unbroken.
79	3:40	150	130	132	
80	3:42	160	132	138	
81	3:45	152	138	140	Cleaned tunnel; now a hole like this. 
82	3:49	150	133	139	Inside tubes - Back 112°F.
83	3:53	165	140	143	
84	3:56	167	140	142	
85	3:58	170	138	137	
86	4:00	165	132	145	
87	4:02	171	150	145	Inside tubes - Front 125°F, Back, 130°F. These were highest obtained - from firing 10 shots in 24 mins. Quit for day.

2 Oct. 1947

Round	Time	Back	Middle	Front	Remarks
88	1:24 PM	100	85	83	Official atmospheric temperature 61°F. from 1:00 PM to 3:00 PM. Atmospheric temperature at firing site 57°F. Noticed rear Al ring cracked for $2\frac{1}{2}$". After this shot, this portion bulged out $\frac{1}{4}$".

ROCKET FIRING #18 (Contd)

1 Oct. 1947

Round	Time	Outside Temperatures Back	Middle	Back	Remarks
53	1:32	152	130	136	
54	1:34	162	132	140	
55	1:37	162	133	145	
56	1:40	162	137	140	
57	1:43	162	140	145	Inside tubes - Front, 110°F, Back, 115°F. Crack turned into break 1/8 x ¼". Firing finger hole larger. Ten shots in 22 minutes.
58	1:58	116	110	104	Had to bring up more rockets and move mount forward.
59	2:02	131	115	120	Interference by persons getting on the firing range interrupted time schedule.
60	2:07	131	112	111	Reset the mount.
61	2:12	119	106	110	
62	2:14	133	114	123	New hole appeared 3/16" x ½" along edge of Al rear ring.
63	2:17	140	119	122	Inside tubes - Front, 105°F, Back, 118°F.
64	2:19	152	128	132	
65	2:22	145	125	135	
66	2:24	158	131	135	
67	2:27	152	129	132	Inside tubes - Front, 110°F, Back, 118°F. For third time, blast came in two parts, a fraction of second apart. Note temperature drop*. Official atmospheric temperature 55°F.
68	3:07	108	90	95	
69	3:10	119	103	113	Atmospheric temperature 80°F in sun.
70	3:12	131	112	120	
71	3:15	150	121	126	

*This may explain temperature drop between rounds 26 and 27 and rounds 14 and 15 although the double blasts were at first thought due to a simultaneous firing on another range.

ROCKET FIRING #18 (Contd)

1 Oct. 1947

Round	Time	Outside Temperatures Back	Middle	Front	Remarks
33	11:42	130	121	125	
34	11:44	135	123	130	
35	11:47	133	121	130	
36	11:49	138	125	130	
37	11:51	138	128	135	Inside tubes - Front, 110°F, Back, 122°F. Official temperature, 50°F.
38	12:49PM	95	82	91	Atmospheric temperature at firing site 73°F and sunny.
39	12:52	108	102	104	Small crack appeared in back end of inner tube.
40	12:55	124	107	110	
41	12:57	130	115	125	
42	12:59	138	125	127	Small hole appeared under 1/2" firing finger hole.
43	1:02	144	125	125	Hole no larger.
44	1:04	149	126	120	Inside tubes - Front, 110°F, Back, 112°F.
45	1:07	150	126	136	
46	1:09	160	138	150	
47	1:11	159	132	150	Hole now this size Inside tubes - Front, 116°F, Back, 118°F.
48	1:21	128	118	124	
49	1:23	140	129	132	Crack and hole no larger.
50	1:25	151	125	133	Another smallcheck at edge of Al ring.
51	1:28	146	128	135	
52	1:30	160	131	142	Inside tube - Back, 114°F. Slight wind at right angle to launcher.

ROCKET FIRING #18(Contd)

1 Oct. 1947

Round	Time	Outside Temperatures Back	Middle	Front	Remarks
12	9:43	100	97	97	Inside tube 80°F both front and back. Broken wood cleaned from tunnel.
13	9:48	99	94	99	At 9:45 atmospheric temperature - 49°F at firing site, clear and almost still. Fairly shady until noon.
14	9:51	118	105	105	Inside tube - 98° back; 80° front.
15	9:55	108	100	108	
16	9:57	113	106	101	
17	10:00	128	112	117	Inside tubes - Front, 100°F, Back, 97°F.
18	10:39	80	80	82	
19	10:42	95	89	92	
20	10:45	110	92	100	Inside tubes - Front, 80°F, back, 84°F. Had to clean tunnel again.
21	10:58	95	90	90	Atmospheric temperature at firing site - 63°F.
22	11:01	112	95	98	
23	11:03	115	105	104	
24	11:06	120	113	115	
25	11:08	120	115	115	
26	11:10	132	122	129	
27	11:13	122	117	117	Inside tubes - Front,95°F; Back, 93°F.
28	11:27	92	97	102	
29	11:30	99	106	108	Temperatures on Rounds 28 and 29 look as though front and back may be reversed.
30	11:34	108	107	105	
31	11:37	115	110	117	
32	11:39	119	112	110	Inside tubes - Front, 100°F, Back, 95°F.

ROCKET FIRING #18 1-2 October 1947

No. of Rockets Fired: 96

Rockets Used: Same as for previous firings. The first ten and the last five were heated to 49°C (120°F) by overnight storage.

Launcher Tube Used: This was a composite tube. The inner tube was made by Continental Diamond Fibre and was a molded tube, Grade AA, 4-9/16" I.D. with 1/8" walls. The outer tube was one of the Al tubes furnished by Rock Island Arsenal and had an internal diameter of 4-13/16" with 5/32" wall thickness. The inner tube was ground to fit tightly inside of the outer tube and protective rings screwed to the outside of the Al tube at front and back. These rings had a stepped construction so that they protected the inner tube.

Results of Firing:

24 Sept. 1947

Round	Time	Outside Temperatures Back	Middle	Front	Remarks
1					Rockets 1-10 heated to 120°F. Inner surface of tube blackened.
2					Small chip on front edge, 1/16 x 1/16 x 1/2".
3					No change.
4					No change.
5					No change.
6					No change.
7					No change - Firing stopped as no more rockets available at Testing Station.
1 Oct. 1947					
8	9:32 AM		Cool to touch		9:00 official atmospheric temperature - 44°F.
9	9:35		Cool to touch		
10	9:38		Cool to touch		
11	9:40	100	92	88	All temperatures are in °F. Started firing with rockets 11-91 at ambient temperatures.

ROCKET FIRING # 17

No. of Rockets Fired: 1

Rocket Used: Same as previous firings.

Launcher Tube Used: This was a composite tube. The inner tube was a Synthane rolled tube, Grade A-M. The outer tube was an Al one which had previously had threads cut on the inside and then later fitted with a protective ring which screwed on the outside.

Condition of Firing: Same as for previous firings.

Results of Firing: Inner tube broke for a distance of 1" from front edge. There was a small amount of delamination. Tube was cracked at back end and the binder appeared to be burned more than is usual for melamine. The back aluminum ring had 1" sections broken from it and was flared in one place.

Conclusions: The breakage of the tube in front and cracking of it in the rear was probably due to bursting pressure as the inner tube was poorly supported due to threading. However, especially at the front, some of the damage could have been due to a greater opportunity for gas to get between the two tubes.

No explanation is offered as to why the resin burned to a larger extent than usual.

When the blast cracked the rear edge of the tube, the tube probably flared enough to allow the gases to get under the lip of the Al ring and accounts for the fact that it was partly broken and flared.

ROCKET FIRING #16 24 September 1947

No. of Rockets Fired: 1

Rocket Used: Same as in Rocket Firing #15.

Launcher Tube Used: The tube was one purchased from U.S. Plywood and was fabricated of "Fiberglas" 143-14 bound with a low pressure resin (probably "Selectron" 5016). It was 36" long, had an I.D. of 4-9/16" with 0.10" walls. The ends had been fitted with Al rings secured by four screws which made holes in inner surface of tube.

Conditions of Firing: Same as in previous firings.

Results of Firing: The front ring was blown off and the tube was severely delaminated for a distance of 3" from front of tube. The edge remaining had a thickness of 0.041" as compared to the original 0.100". The delaminated part was in single threads and 1/4 to 1/2" wide strips rather than a single sheet. The inner surface at the back part of the tube showed the resin had partly burned.

Conclusion: See Rocket Firing #19, Conclusions.

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ROCKET FIRING #15 24 September 1947

No. of Rockets Fired:	1
Rocket Used:	An M17, 4.5" practice rocket as prepared by Loading Branch. Rocket was heated at 49°C (120°F) for 18 hours.
Tube Used:	The tube used was one furnished by U.S. Plywood and was made of "Fiberglas" 181-14 with a low pressure resin (probably "Selectron" 5016). It was 36" long, 4-9/16" I.D. with wall thickness of 0.15". This was fitted with Al rings front and back, secured by four screws which punched holes through inner wall of tube.
Condition of Firing:	Same as previous firings.
Results of Firing:	The front ring was blown off. The inner 2/3 of the tube was pealed back for a distance of 4". (Wall which was left was 0.056" thick as compared to original 0.15"). The inner portion was peeled back as whole sheets. Back portion of tube was still white.
Conclusions:	See Rocket Firing #19, Conclusions.

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ROCKET FIRING #14 (Contd)

Conclusion:

The threading of the outer tube weakened it so that when the blast found a crack through which to enter, it was unable to withstand the strain.

The gas friction (approx. 1000#) was enough to shear the two small rivets holding the stop.

It is now considered better design to construct protective rings so that they screw on to the outside of the aluminum tubes and present an unbroken surface to the blast.

ROCKET FIRING #14 27 August 1947

No. of Rockets Fired: 1

Rocket Used: An M-17, 4.5" practice rocket as prepared by Loading Branch. Rocket was heated in a 49°C (120°F) oven for 21 hours.

Launcher Tube Used: This was a composite tube. The outer tube was an aluminum tube furnished by Rock Island Arsenal. The I.D. was 4-13/16" with 5/32" walls. The inner tube was a Synthane AA-M tube ground to fit inside the aluminum tube. This had 4-9/16" I.D. with 1/8" walls. The front and back edges of this inner tube were protected by threadings 3/4" wide which screwed into the outer tube. These had a medium thread (approx. 16 threads/inch).

Condition of Firing: Same as previous firing.

Result of Firing: The front end of the outer tube was flared out. This was especially bad in one section of about 3-1/2", the flare extending the full depth of the threads.

A 3 x $\frac{1}{4}$" stop which had been riveted to the back ring was blown off. This had only been held by 2-1/8" rivets. The front edge of this back ring was eroded where it evidently had extended beyond the plastic tube. Where the tube was in contact with the supporting frame in the rear, a downward component of the blast partially flattened the tube.

Some of the resin burned off the inside of the tube. A small portion of this had been deposited in the threads under the back ring where it re-solidified.

A very small portion of the inner tube was delaminated where it extended beyond the protective ring.

ROCKET FIRING #13 5 August 1947

No. of Rockets Fired: 1

Rocket Used: An M-17, 4.5" practice rocket as prepared by Loading Branch. Rocket was heated in an air oven at 49°C (120°F) for 22 hours.

Launcher Tube Used: The tube used was a 3 ft. section cut from the rear end of one 10 ft. tube from an M-10 aircraft launcher cluster. This is a paper based laminate, with a phenolic binder.

Condition of Firing: Same as for Rocket Firing #12.

Result of Firing: Upper 3/4 of tube was shattered for a distance of 1/2 the tube length from the front. Some of the pieces were fairly large (6" to 8" long). Lower portion which was lying on mount was not broken. The back half of the tube was not broken.

Conclusions: While this tube may have been satisfactory for its original use, it has entirely too little bursting strength to be of value when firing heated, spin-stabilized rockets.

ROCKET FIRING #12 (Contd)

the circumference. This portion contained the back stop. A strip of about three layers was delaminated from the entire length of the tube. This strip was in the same plane as the piece which was blown off. The cloth in the other two sections between the rails was unaffected.

Conclusions: Delamination resistance of "Fiberglas"/melamine tubes seems to be fairly good when the front edge is protected except for spots where holes have been drilled to give the delamination a start. These holes are especially bad when they form a straight line in the circumferential plane. If these holes were staggered, their bad effect might be lessened. No actual need is seen for the small plate in front of the back stop. If this could be eliminated, the structure should be much stronger. At the same time, the back stop is held in place by a row of three rivets and there seems to be no especial tendency for breaking there. It is not known whether this is due to the fact that larger rivets are used here or if the location is better. It may be that in the case of the small plate, it is located where the initial blast hits it for a longer period of time while the rocket is overcoming inertia.

While some resin is boiled out of the fabric, it is not yet proven either way that this would be of a sufficient amount to render the tube incapable of lasting for 101 rounds.

ROCKET FIRING #12 5 August 1947

No. of Rockets Fired: 4

Rockets Used: M-17 practice rockets as prepared by Loading Branch. Rockets were heated in an air oven at 49°C (120°F) for 19 hours.

Launcher Tube Used: The same tube which was successfully used in Rocket Firing #11 was used.

Condition of Firings: Same as Rocket Firing #11.

Results of Firings:

1. 10:35 AM - Temperature of the tube before any firing was done was 21°C (70-71°F). A rocket was fired and the temperatures were taken. These showed that the rivets were 47°C (117°F) while the walls of the tube were at 28°C (82°F). No visible damage was done to the tube.

2. 10:50 AM - Another rocket was fired and the temperature again taken. The rivets were 50°C (122°F) while the tube was 29°C (85°F) at the front end and 50°C (122°F) at a point 5" from rear of tube. Small scratches appeared on each side of the rivets at a distance of 3/16" from the rivet head. These were along the longitudinal axis. The inside of the tube at the back looked as though the resin had boiled up some.

3. 11:15 AM - Another rocket was fired and the temperatures were now 35°C (95°F) and 39°C (102°F) on the tube and 41°C (105°F) and 63°C (145°F). on the rivets. Delamination started around the back stop. The rivets in face plate immediately ahead of back stop were torn.

4. 11:30 AM - Another rocket was fired and the temperatures were 36 and 41°C (97 and 105°F) on the tubes and 43°C (110°F) and 65°C (150°F). on the rivets. A 3" piece of the tube was blown off for a distance of 1/3 of

ROCKET FIRING #11 16 July 1947

No. of Rockets Fired: 1

Rocket Used: A M-17 practice rocket as prepared by Loading Branch. Rocket was heated in a steam heated chamber (Bldg. 165) at 49°C (120°F) for 29 hours.

Launcher Tube Used: Tube was one furnished A.D. Little, Inc by Synthane Corporation and was fitted with rails, firing fingers, and stops by Rock Island Arsenal. This was of glass/melamine construction, 5" I.D. x $5\frac{1}{2}$" O.D., 36" long. The I.D. of the rails was 4-9/16". Tube has Synthane designation Grade GLCC natural. Filler was Owens-Corning "Fiberglas" #128, continuous filament. Resin was melamine-formaldehyde thermosetting type and was present in the amount of 38-42%. Protective ring was fitted by Rock Island Arsenal and was left in place on this one as to differentiate from Rocket Firing #7.

Condition of Firing: Same as previous firings except that new, wider ($2\frac{1}{2}$") clamps were used. These allowed the tube to slide back only $\frac{1}{4}$" whereas the clamps used formerly let it slide 3-5".

Result of Firing: Tube did not burst upon firing. No delamination either at front edge nor in back where holes had been punched for firing fingers. Quite a lot of heat was noted being transmitted through the wall over the rails. Rivet holes showed no elongation.

Conclusions: Since 3/16" glass/melamine tube did not burst, this 1/4" tube was not expected to.

The small Al disk is sufficient to prevent delamination. However, the mounting of this ring will offer problems when no rails are used. The heat noted may have been carried through the walls by the rows of rivets or it may have been conducted through the glass wall. It is impossible to say which.

No serious difference in coefficients of expansion of Al and glass laminate.

ROCKET FIRING #10

No. of Rockets Fired:	1
Rocket Used:	Same as Rocket Firing #9.
Launcher Tube Used:	Continental Diamond Fibre Co.'s AA-PF molded tube, 4-9/16" x 4-13/16", fitted tightly into a 4-13/16" x 5-1/8" Al tube.
Condition of Firing:	Same as Rocket Firing #9.
Result of Firing:	One half of inner tube disappeared. Edge of remainder of tube was at right angles to tube surface. No apparent damage to Al tube. Remainder of tube charred on the inside.
Conclusions:	Front of tube needs protection. Indicates possibility that gases got between the two tubes and broke inward. Phenol-formaldehyde is essentially not heat resistant enough.

ROCKET FIRING #9

No. of Rocket Fired: 1

Rocket Used: Same as in Firing #8.

Launcher Tube Used: Synthane A-M rolled tubing, 4-9/16" x 4-13/16" ground to a tight fit in an Al tube 4-13/16" x 5-1/8". The Al tube used here and in subsequent firings was furnished by Rock Island Arsenal. It had an I.D. of 4-13/16" with 5/32" walls. It was a sand casting made of Al base alloy, Class 4, Federal Specification QQ-A-601. Its physical properties were - tensile strength, 29,000 psi; elongation, 6% in 2".

Conditions of Firing: Same as in Firing #8 except that front edge of tubes had no protection.

Results of Firing: The inner tube was blown away for a distance of 5" from front of tube. Edge of remainder of tube was leveled. No apparent damage to the Al tube. No damage to rear of inner tube where cuts had been made to allow tube to fit around stop attached to Al tube.

Conclusions: Front edge protection is needed. The failure looked to be delamination, due to gas getting between the two tubes.

ROCKET FIRING #8

No. of Rockets Fired: 1

Rocket Used: A M-17, 4.5 inch practice rocket as prepared by Loading Branch. Rocket was heated in air oven at 60°C (140°F) for 16 hours, removed and allowed to cool for 2 hours in cardboard container. Temperature of 60°C (140°F) was obtained through malfunctioning of thermostat on oven.

Launcher Tube Used: Tube was one furnished by Arthur D. Little, Inc. by Synthane Corporation and was fitted with rails, stop and firing fingers by Rock Island Arsenal. This was of glass fabric/phenolic construction, 5" I.D. x 5-3/8" O.D., 36" long. The I.D. of the rails was 4-9/16". Tube has Synthane designation Grade GLCC natural. Filler is Owens Corning "Fiberglas" #128, continuous filament. Resin is phenol-formaldehyde thermosetting type and is present in amount of 38-42%. The protective ring was removed from the front end of the tube but the tube was fitted into a step in the faceplate.

Condition of Firing: Same as Rocket Firing #7 except that exact temperature was more uncertain, due to the fact that no pyrometer was available.

Result of Firing: The tube did not burst upon firing. Very severely delaminated at front edge (more so than melamine tube). No delamination around rivets holding firing fingers in place at back of tube.

Conclusions: This tube has required bursting resistance. Delamination is caused by burning away of phenol-formaldehyde binder. At the back where flame conditions were less severe, phenol-formaldehyde proved to be a better binder than melamine.

Might be advantageous to increase amount of binder.

ROCKET FIRING #7 (Contd)

Conclusion:

This thickness of tube has a calculated bursting strength of 3000 lbs. (accepting Synthane's figure of 40,000 psi tensile strength) and seems capable of resisting bursting.

Delamination is too severe for acceptable performance. Rivet holes should be avoided as much as possible as they provide a start for delamination

Difference in coefficient of expansion was not great enough in this case to cause rivet holes under rails to elongate.

It may be possible to cut down delamination by use of a binder with greater adhesive strength or by using a molded tube.

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ROCKET FIRING #7 — 24 June 1947

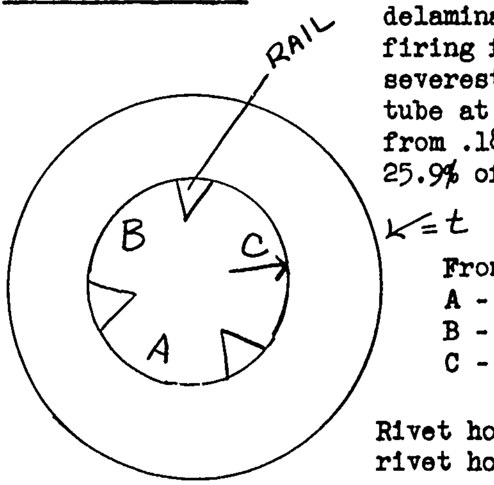
No. of Rockets Fired: 1

Rocket Used: A M-17, 4.5" practice rocket as prepared by Loading Branch. Rocket was heated for 22½ hours in an air oven maintained at 55°C (130°F).

Launcher Tube Used: Tube was one furnished Arthur D. Little, Inc. by Synthane Corporation and was fitted with rails, firing fingers, and stops by Rock Island Arsenal. This was of glass fabric/melamine construction, 5" I.D. x 5-3/8" O.D., 36" long. The I.D. of the rails was 4-9/16". Tube has Synthane designation Grade GLCC natural. Filler is Owens-Corning "Fiberglas" #128, continuous filament. Resin is a melamine-formaldehyde thermosetting type and is present in amount of 38-42%. Protective ring was removed from the front of the tube but this fitted into a step in the face plate.

Condition of Firing: Same as for Rocket Firing Test #6.

Result of Firing: The tube did not burst upon firing. The tube did delaminate at front edge and around rivets holding firing fingers in place at back of tube. The severest delamination was on the bottom of the tube at the front edge where the tube was reduced from .1875" to 0.1390". This represents a loss of 25.9% of the original thickness.



Front edge of tube, looking into tube.
A - Worst delamination, t = .1390
B - Some delamination, t = .1480
C - No delamination, t = .1850

Rivet holes under rails show no elongation. One rivet holding stop in place was blown out.

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ROCKET FIRING #6 (Contd)

Conclusions:

The length of the pieces found was probably determined by the position of the clamps. Weakening by punching of rivet holes is debatable.

The break either occurred before the rocket could leave the tube or else the face plate offered insufficient protection from the back blast.

The larger than usual flame may have been due to the complete shattering of the tube which allowed it to spread more or may have been due to a "hot" rocket.

The tube is definitely incapable of withstanding the bursting pressure developed.

CONFIDENTIAL

ROCKET FIRING #6 24 June 1947

No. of Rockets Fired: 1

Rocket Used: A M-17, 4.5" practice rocket as prepared by Loading Branch, brought to 55°C (130°F) by 22 hours in an air oven. (The 130°F oven was the only one available and it was believed that the rocket would lose 10° of heat in being transferred to the firing location).

Launcher Tube Used: Tube was one furnished to Arthur D. Little, Inc. by Synthane Corporation and was fitted with rails, firing fingers, and back stop by Rock Island Arsenal. Tube was of cotton cloth/phenolic construction, 5" I.D. x 5½" O.D., 36" long. The I.D. of rails was 4-9/16". Tube has Synthane designation Grade CB natural. Filler is coarse weave cotton fabric, bleached, having thread count of 48 x 48 and weight of 8-10 oz. per square yard. Resin is phenol-formaldehyde thermosetting type and is present in amount of 48-52%. Protective ring was removed from front of tube but this fit into a step in the face plate.

Condition of Firing: Reconstructed mount with 3/4" steel face and flange made of boiler plate rather than cast iron. Mount was of all welded construction except that flange was bolted to face plate for interchangeability. Elevation was $0^\circ \pm 5^\circ$, rocket was at temperature of 130 -10°F.

Result of Firing: The tube was completely shattered by the blast. A few pieces were found which were 12-14" long and 2" wide. Breakage was sharp and entirely at right angles to surface of tube. Pieces still riveted to the guide showed that in some cases the break came along the line of rivet holes; in other cases it did not. The guide rails were wrapped back around the front clamp. There was very little evidence of burning or delaminating. The flame noted was about twice that usually observed.

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ROCKET FIRING #5 28 May 1947

No. of Rockets Fired:	1
Rocket Used:	A M-17 - 4.5" practice rocket prepared by Loading Branch, brought to $49^{\circ}C$ ($120^{\circ}F$) by 18 hours in an oven.
Launcher Tube Used:	A Continental Diamond Fiber Company molded tube, Grade AA-PF, 4-9/16" I.D., 1/4" thick, 36" long.
Conditions of Firing:	Mount as used in Rocket Firing #3 and 4, $0^{\circ} \pm 5^{\circ}$ elevation, rocket heated to $49^{\circ}C$($120^{\circ}F$).
Results of Firing:	The 1/4" tube was also broken by the force of the blast. The largest piece found was a 12" section from the rear of the tube. This was not split by the explosion. Phenol-formaldehyde was partly burned off of inside layer. The blast also wrecked the mount, bending the front plate, splitting the 1" thick 4" x 9" cast iron flange, and shearing off bolts.

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ROCKET FIRING #4 28 May 1947

No. of Rockets Fired: 1

Rocket Used: A M17 - 4.5" practice rocket prepared by Loading Branch. Brought to 49°C (120°F) by 17 hours in an oven.

Launcher Tube Used: Same Synthane rolled tube Grade AA-M, 4-9/16" I.D., 1/8" thick, 31¼" long (cut from 36" tube by cutting equal size pieces from each end) as used in Rocket Firing #3.

Conditions of Firing: Mount as used in Rocket Firing #3, same tube, $0^\circ \pm 5^\circ$ elevation, rocket heated to 49°C (120°F).

Results of Firing: Launcher tube was burst completely into pieces. The largest piece found was a back section about 8½ inches long and this had been split. Melamine binder had been pretty well burned off for one layer on inside of tube. Some of small pieces found were about 1/2 of original thickness, indicating delamination as well as bursting. This delamination may have been due to breaking rather than as a result of the back blast.

ROCKET FIRING #3 26 May 1947

No. Rockets Fired: 1

Rocket Used: One of first group of 200 prepared as per job order of 18 February 1947.

Launcher Tube Used: Synthane rolled tube AA-M. 4-9/16" x 4-13/16" x 31¼". Cut down from 36" by cutting equal portions from each end.

Firing Conditions: Mount placed on top of 75 mm. cannon, 0° elevation. Two metal straps with 1/4" rubber pads over tube, tightened down to finger tight only, to prevent making tube egg shaped. I.D. of flange was 4-5/8" which allowed 1/32" of tube to extend inward from flange to eliminate possibility of rocket hitting flange.

Results of Firing: Tube remained in mount although it slid back 3/4". Might pull clamps down a little tighter and still allow rocket to slide freely. I.D. of tube still measures 4.56" (4-9/16"). Appearance tends to indicate a small layer of resin gone from inside but not enough to measure. Front edge shows delamination of one layer for distance of 1/16" in spots.

ROCKET FIRING #2 22 April 1947

Number of Rockets Fired:	1
Rocket Used:	One of first group of 200 prepared as per job order of 18 February 1947.
Launcher Tube Used:	Synthane rolled tube AA-PF. 4-9/16" I.D., 1/8" thick, 31¼" long (cut from 36" tube by cutting equal pieces from each end).
Firing Conditions:	Pendulum mount, $0^{\circ} \neq 5^{\circ}$ elevation, two metal straps over tube.
Results of Firing:	Tube was thrown out and upward by force of exhaust gases which bent strap iron frame work and allowed tube to escape. Pieces were broken from the tube at the front end (on which it lit) after a flight of approximately 75 feet in the air. Launcher tube was blackened on inside, especially at front end. One small section (1/2 x 1") shows side wall reduced to approx. 1/2 with a charred appearance. How much of this was due to burning and how much due to impact with ground is unknown. Tube did not split.

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ROCKET FIRING #1 17 April 1947

Number of rockets fired: 1

Rockets Used: One of first group of 200 prepared by Loading.

Launcher tube used: Synthane rolled tube Grade AA-M, 4-9/16" I.D., 1/8" thick, 31¼" long (cut from 36" long tube by cutting off equal pieces at each end).

Conditions of Firing: Wooden mount, $0^{\circ} \not\angle 5^{\circ}$ elevation, 3 metal straps around launcher tube.

Results of Firing: Mount was toppled over backwards (probably by force of exhaust gases), pieces were cracked off launcher tube at back end (probably from toppling of mount), launcher tube was blackened on the inside and on the outside near the front, launcher tube did not burst, tube thickness was generally unchanged.

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ROCKET FIRING #1 17 April 1947

Number of rockets fired:	1
Rockets Used:	One of first group of 200 prepared by Loading.
Launcher tube used:	Synthane rolled tube Grade AA-M, 4-9/16" I.D., 1/8" thick, $31\frac{1}{4}$" long (cut from 36" long tube by cutting off equal pieces at each end).
Conditions of Firing:	Wooden mount, $0^{\circ} \not\angle 5^{\circ}$ elevation, 3 metal straps around launcher tube.
Results of Firing:	Mount was toppled over backwards (probably by force of exhaust gases), pieces were cracked off launcher tube at back end (probably from toppling of mount), launcher tube was blackened on the inside and on the outside near the front, launcher tube did not burst, tube thickness was generally unchanged

CONFIDENTIAL

PICATINNY ARSENAL, DOVER, N. J.

REPORT FROM THE CHEMICAL LABORATORY

mjd

REPORT NO. 119227

DATE 4 November 1946

Re: Non-Metallic Rocket Launching Tubes

INTRODUCTION:

The metallic tubes used in multiple launchers become quite hot after firing one or two rockets, and it has been feared that these hot tubes may cause premature firing of subsequent rounds inserted into the tubes. Accordingly, the Office of the Chief of Ordnance has been interested in the possibility of using plastic tubes for this application with the expectation that the lower thermal conductivity and/or the lower heat capacity of the plastic as compared with metal would result in less of a temperature rise in rounds inserted subsequently. The Office of the Chief of Ordnance directed (O.O. 471.94/972, ORDBB 471.94/1900) that a preliminary investigation be conducted to determine whether or not plastic tubes showed any improvement over metal tubes as far as this effect is concerned and to determine which types of plastic constructions warrant further consideration from the point of view of mechanical properties.

OBJECT:

To determine (1) whether or not plastic tubes are superior to metal tubes in remaining cooler during firing and (2) which plastic constructions show the most promise in resisting bursting and/or delamination during firing.

RESULTS:

Results obtained in comparative firing tests are shown in Table I. None of the plastic tubes showed a serious tendency to heat, and all were greatly superior to the metal tube in this respect. The fabric base tubes showed less tendency to burst than did the paper base tubes, and the tubes made with thermosetting resins were the least inclined to delaminate. The best tube of all was an asbestos base phenol-formaldehyde tube which withstood twenty-two firings at five minute intervals without bursting or delaminating and was not too hot to handle with bare hands even after seventeen rounds.

DISCUSSION OF RESULTS:

Since all plastics are low in thermal conductivity and in heat capacity relative to steel, no plastic was originally excluded from consideration in connection with this project. However, it soon became apparent that only laminated tubes are commercially available in the size required, and, accordingly, extruded tubing was eliminated from further consideration. Three principal classes of plastics tested were high pressure thermosetting laminates, low pressure thermosetting laminates, and high pressure

1A

thermoplastic laminates.

It was not intended that this investigation should be an exhaustive survey indicating the best tube to use; it was intended instead that this should be a preliminary investigation to determine whether or not plastic tubes show any advantage in heat characteristics relative to metal tubes and, if so, which plastic constructions warrant further and detailed investigation for this application. With this in view, firing tests under actual service conditions were not necessary, and firing tests under constant conditions only were required. The test used consisted of statically firing a fully loaded rocket mounted one foot ahead of the plastic tube and in line with the tube. By this arrangement, the tube received practically the full blast of gases from each firing. Since the 4.5" rocket usually travels about 80 feet before burning is complete, it is apparent that only a small portion of the gases would strike the tube in actual practice, and it is apparent that the test set-up used in this investigation is more severe than the firing conditions encountered in service with the possible exception of internal bursting pressure applied. Comparison of the data in Table I shows that the asbestos and the fabric base high pressure phenol-formaldehyde laminates were outstandingly superior to the other materials in mechanical strength and in resistance to delamination. None of the high pressure laminates failed principally by delamination, but the paper base tubes did show some delamination and were lower in mechanical strength than the other thermosetting laminates.

In contrast with the high pressure laminates, the low pressure laminates failed by delamination.

The tests on thermoplastic laminates were not strictly comparable with those on the other materials, because (1) the thermoplastic laminated tubes were not seamless, and (2) the thermoplastic tubes could not be gripped firmly in the vise due to the lower wall thickness and lower rigidity of these tubes. The thermoplastic tubes all failed by bursting but this bursting was at least partly promoted by the weak seam which was present and by the fact that tubes cocked in the vise and so did not take the full blast in a purely longitudinal direction as did the other tubes. Although the bursting of the thermoplastic laminated tubes cannot be taken as conclusive evidence that they would be unsatisfactory for this application, other characteristics do eliminate them from further consideration. The thermoplastic tubes soften from the heat under conditions which did not effect the thermosetting tubes. This softening was evidenced by a tendency of the polymer to flow under the influence of the stream of gases and by the softening of the tube where it came in contact with metal heated by the blast. The tubes softened where gripped by the metal vise. Since metal retaining parts would be required in the launcher assembly, there would be points of contact between metal and plastic, and this plastic would soften at such points.

2A

As shown in Table I, tubes Nos. 10, 11, and 12 were coated on the inside with various varnishes including both silicone base varnish and aluminum pigmented varnish. This was done in accordance with a suggestion included in correspondence (OO 471.94/1400, ORDBB 471.94/1900-5) from the Specifications and Materials Section from the Ordnance Office. The purpose of adding these coatings was to increase the resistance to abrasion by the blast of gases and/or decrease heat absorption by the plastic tube. Unfortunately, the coated tubes failed in such a manner that no conclusion could be drawn concerning the effect of the coatings and there were not available sufficient tubes of the stronger constructions to permit test of coatings on the more durable types.

It is apparent from these data that future considerations should be given to high pressure thermosetting laminates rather than to other classes of materials. The ultimate choice within this class will have to be made on the basis of requirements such as weight, abrasion resistance, and commercial availability which apply to the intended use. Asbestos base tubes will be heavy, more expensive, and less readily available than the other compositions. Fabric base tubes will be heavier and less readily available in times of shortages than paper base materials. The paper base tubes will be the lightest and most generally available but are inferior in mechanical strength to the other tubes. If it develops that maximum strength is not required, it is quite possible that paper base tubes will prove adequate for this application.

CONCLUSIONS:

Plastic tubes show very little tendency to become hot when exposed to the exhaust blast from rockets and are greatly superior to steel tubes in this respect.

High pressure thermosetting laminates are superior to low pressure thermosetting laminates or to thermoplastic laminates in resistance to destruction by the exhaust blast from rockets.

Asbestos base and fabric base high pressure thermosetting laminates are considerably superior to paper base high pressure thermosetting laminates in blast resistance.

Further investigation of plastic tubes for launchers is warranted on the basis of the performance of the best of the materials in these tests. Further work should be on the high pressure thermosetting laminates, and the selection of asbestos base, fabric base, or paper base material should be made according to considerations of weight, abrasion resistance, commercial availability, etc. as required for this application.

SPOBB-43A

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PICATINNY ARSENAL, DOVER, N. J.

REPORT FROM THE CHEMICAL LABORATORY

REPORT NO. 119227

DATE 4 November 1948

EXPERIMENTAL PROCEDURE:

Preparation of Tubes

Tubes Made with Low Pressure and Contact Resins - Five experimental tubes were made in the laboratory using two low pressure or contact laminating resins with three different base materials. Two tubes were made using "Laminac" 4201, an unsaturated polyester, and three were made using "Melmac" 403, a low pressure melamine-formaldehyde resin.

The two tubes using "Laminac" 4201 were made by coating the resin on the base material, wrapping this coated material around a mandrel, and finally curing in an oven. Experimental Tube No. 1 was made with a base of glass fiber fabric ("Fiberglas" No. ECC-11-162) measuring twelve inches wide and five yards long. The "Laminac" 4201 was prepared for coating by heating 500 grams of the resin on a steam bath at 60°C and adding 10 grams of "Luperco ATP" (a mixture of equal weights of benzoyl peroxide and triphenyl phosphate) being stirred in slowly until completely dissolved. This resin was then spread over the surface of the "Fiberglas" by means of a wooden knife coater. The doctor knife on the coater was set to give an equal weight of resin to fabric. The coated fabric was then wrapped around a smooth steel pipe measuring 4.5 inches outside diameter with a thin sheet of cellophane as release agent between the coated fabric and the steel mandrel. This assembly was then cured for one hour at 150°C (300°F). The mandrel was forced out of the tube by striking several times with a hammer.

Experimental Tube No. 2 was made in exactly the same manner as Experimental Tube No. 1 except that the base material used was Duck, Cotton, C.D. No. 10, measuring 12 inches wide and five yards long, instead of the "Fiberglas". As the duck is much heavier than the glass fabric, it required 1000 gms. of "Laminac" 4201 and 20 grams of catalyst.

The three tubes containing "Melmac" 403 were made by impregnating the base material with the resin, wrapping this impregnated material around a mandrel, and finally curing in an oven. Experimental Tube No. 3 was made with a "Fiberglas" base (ECC-11-162) measuring 12 inches wide and five yards long. The "Melmac" 403 was prepared for impregnating by first mixing 100 gms. of "Powder B" with 900 gms. of "Powder A" and adding this mixture slowly to 1000 gms. of a 1-1 mixture of water and ethyl alcohol with vigorous agitation until dissolved. The "Fiberglas" was then submerged in this resin solution and was passed under the wooden doctor knife, which was adjusted to scrape off the excess resin solution. This material was then air-dried and wrapped around a wooden mandrel measuring 4-9/16 inches in diameter. The wooden mandrel was first coated with Carnauba wax before wrapping the material around it. This assembly was then cured for one hour at 150°C. The mandrel was pushed out of the cured tube by means of a wooden mallet.

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Experimental Tube No. 4 was made in exactly the same manner as Experimental Tube No. 3 except that the base material was cotton cartridge cloth, Grade A (Spec. 50-11-65A) measuring 12 inches wide and 10 yards long.

Experimental Tube No. 5 was made in exactly the same manner as Experimental Tube No. 3 except that the base material was Kraft wrapping paper measuring 12 inches wide and 20 yards long.

One end of each of the above five tubes was cut off by means of a band saw in order to present a uniform end surface for testing.

High Pressure Laminate Tubes - This class of tubes was obtained from the Synthane Corporation and from the General Electric Company. The "Synthane" tubes were of standard resin content, while the General Electric tubes were of very low resin/paper ratio. Tubes 14-16 inclusive were from Synthane Corporation, while Tubes 10-13 inclusive were from General Electric Company.

Thermoplastic Laminate Tubes - Thermoplastic laminated sheets submitted by the Hercules Powder Company were formed into tubes 24 inches long and 4.5 inches I.D. in the Tinshop. The sheets were cut to proper size and were bent over a flame in the easiest bending direction. This made the axis of the tube parallel with the glass fibres rather than perpendicular to them in the case of the glass fabric laminates. The bent sheet was then rapidly run through a forming machine set to produce a somewhat smaller diameter than desired, and the tube was then forced onto a mandrel of the desired size and allowed to cool. Bands of steel were screwed around the tubes to keep the joint from opening.

Varnished Tubes - Silicone varnish "Dow Corning 993" was diluted with an equal volume of toluene and was sprayed on the inner side of the standard laminated phenol-formaldehyde tube. After air drying for one hour, the tube was placed in an oven at 77°C (170°F) for one hour and was then placed in an oven at 150°C (302°F) for six hours.

Silicone varnish "Dow Corning 993" was diluted with an equal volume of toluene. Aluminum powder (extra fine) was then mixed with the varnish in the ratio of diluted varnish/aluminum powder (85:15) by weight. The solution was applied and the coating was treated as described in the above paragraph.

Cyclopentadiene "HB-100" and "Bakelite BL3128" were diluted to spraying consistency and were sprayed on the inner side of standard laminated phenol-formaldehyde tubes. After air drying for one hour, the tubes were placed in an oven at 77°C (170°F) for one-half hour and were then placed in an oven at 150°C (302°F) for 30 minutes.

MATERIALS USED:

Material	Characteristics	Source
Thermoplastic laminate, Hercules 668-91-1	Fiber glass base; ethyl cellulose, approx. 0.125" thick	Hercules Powder Company
Thermoplastic laminate, Hercules 668-91-2	Fiber glass base; cellulose acetate approx. 0.125" thick	Hercules Powder Company
Thermoplastic laminate, Hercules 668-95-1	P-18 duck base, ethyl cellulose, approx. 0.20" thick	Hercules Powder Company
Thermoplastic Laminate, Hercules 668-95-2	P-18 duck base; cellulose acetate, approx. 0.200" thick	Hercules Powder Company
Dow Corning 993	Silicone baked finish	Dow Corning Corporation
HB-100	Cyclopentadiene baked finish	Resinous Products & Chemical Company
"Bakelite BL3128"	Baked finish	Bakelite Corporation
Aluminum powder	Extra fine	Aluminum Co. of America
Duck Cotton, O.D. No. 10	Cotton duck, Spec. CCC-D-771 10 oz./sq.yd.	Industrial Stores Division
Cartridge Cloth, Grade A	Cotton fabric, Spec. 50-11-65A, approx. 5 oz./sq. yd.	Industrial Stores Division
"Synthane" XK	Paper base, phenol-formaldehyde molded tube	Synthane Corporation
"Synthane" L	Fabric base, phenol-formaldehyde molded tube	Synthane Corporation
"Synthane" AA	Asbestos base, phenol-formaldehyde molded tube	Synthane Corporation

PICATINNY ARSENAL, DOVER, N. J.

REPORT FROM THE CHEMICAL LABORATORY

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MATERIALS USED: (Cont'd)

Material	Characteristics	Source
"Textolite"	Paper base, phenol formaldehyde wrapped tubes with low resin content	Obtained indirectly from General Electric Company through surplus supplies of aircraft launcher tubes.

Work by:
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PICATINNY ARSENAL, DOVER, N. J.

REPORT FROM THE CHEMICAL LABORATORY

REPORT NO. 119227

DATE 4 November 1946

TABLE I

Firing Tests on Plastic Launcher Tubes

Tube No.	Tube Construction: Base	Tube Construction: Resin	Rounds Fired	Temperature of Tube	Condition of Tube at End of Firing
High Pressure Molded Thermosetting Laminates:					
15	Asbestos	Phenol-formaldehyde	22	Became hot after 17 rounds	No delamination and no failure by bursting, but tube was broke due to twisting in the vise.
14	Fabric	Phenol-formaldehyde	20	Slightly warm	No delamination after 19th round. Tube burst on the 20th round.
16	Paper	Phenol-formaldehyde "Bakelite BL3128" coating	5	Cool	Slight delamination and tube was broken due to twisting in the vise.
13	Paper	Phenol-formaldehyde	4	Cool	Slight delamination and tube was broken due to twisting in the vise.
12	Paper	Phenol-formaldehyde Cyclopentadiene coating	4	Cool	Slight delamination and tube was broken due to twisting in the vise
10	Paper	Phenol-formaldehyde Silicone varnish coating	2	Cool	Burst.
11	Paper	Phenol-formaldehyde Silicone varnish Aluminum powder coating	1	Cool	Burst.

/A

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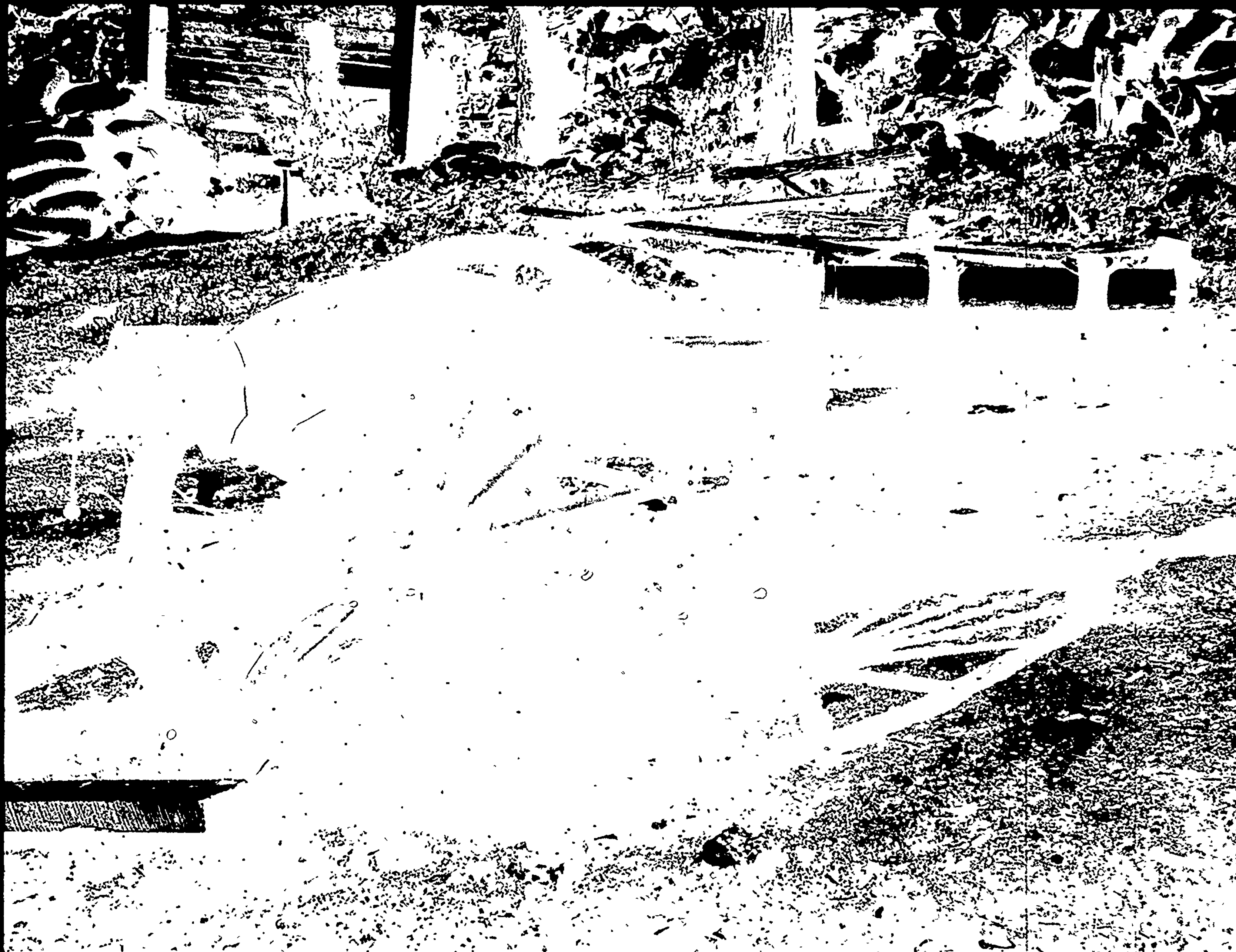
TABLE I (Contd)

Tube No	Tube Construction Base	Resin	Rounds Fired	Temperature of Tube	Condition of Tube at End of Firing
High Pressure Molded Thermoplastic Laminates:					
8	P 18 Duck	Ethyl cellulose	2	Cool	Resin partly melted after first round. Tube burst on the second round.
9	P 18 Duck	Cellulose acetate	1	Cool	Burst
7	"Fiberglas"	Ethyl cellulose	1	-	Tube burst.
Low Pressure Molded Thermosetting Laminates:					
1	"Fiberglas"	"Laminac" 4201	3	Cool	Delaminated after three rounds.
3	"Fiberglas"	"Melmac" 403	2	Cool	Delaminated after two rounds.
2	Canvas	"Laminac" 4201	1	Cool	Delaminated.
4	Cotton Cartridge Cloth	"Melmac" 403	1	Cool	Delaminated.
5	Paper	"Melmac" 403	1	-	Burst.
Control:					
-	Steel (Section of T-100 Metal Launching Tube)		2	Too hot to handle after one firing	Unaffected.

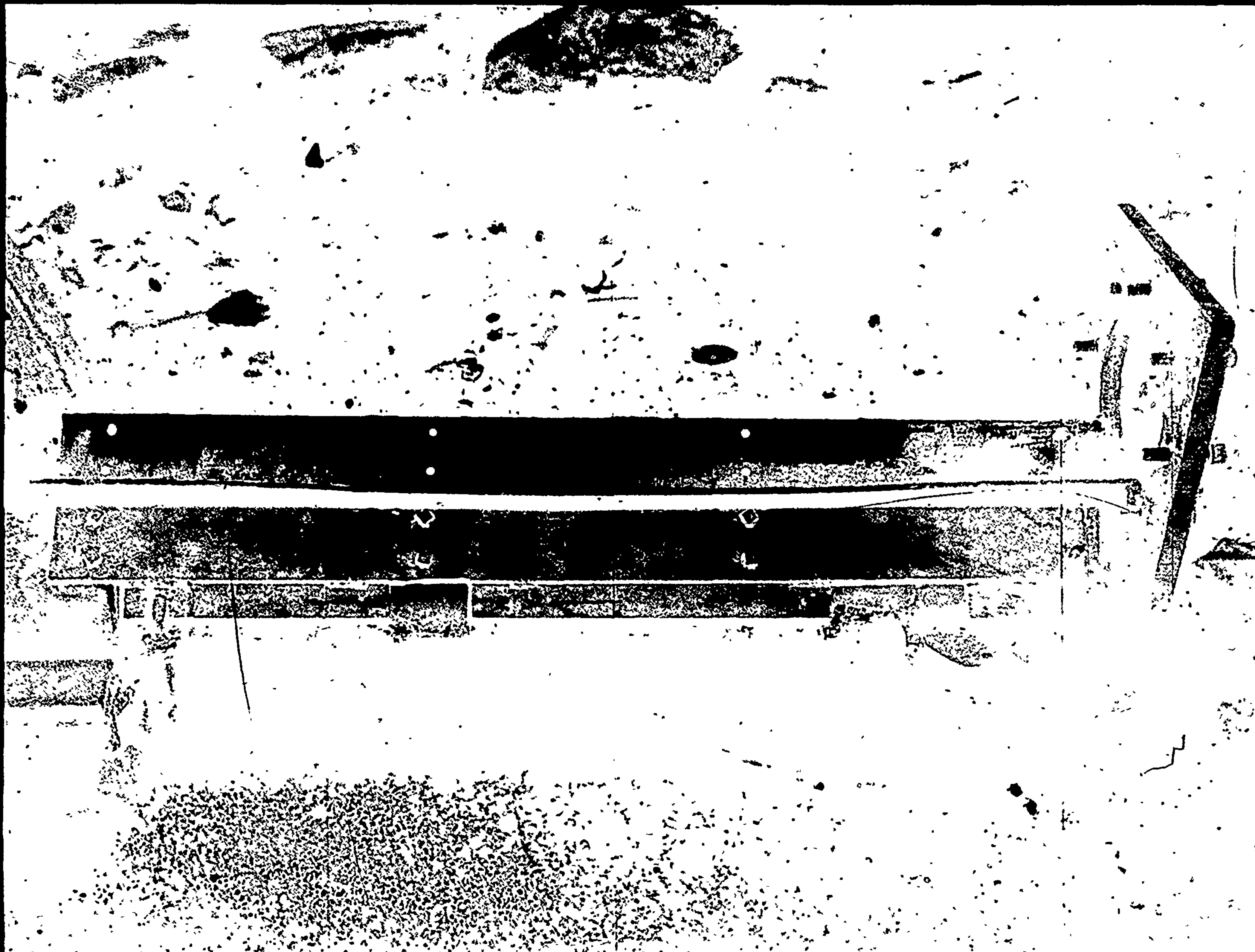


M-33919 | Jan 1948 | PICATINNY ARSENAL | ORDNANCE DEPARTMENT

(CONFIDENTIAL) Mount for Launcher, Rocket, 4.5 Inch, with Launching Tube

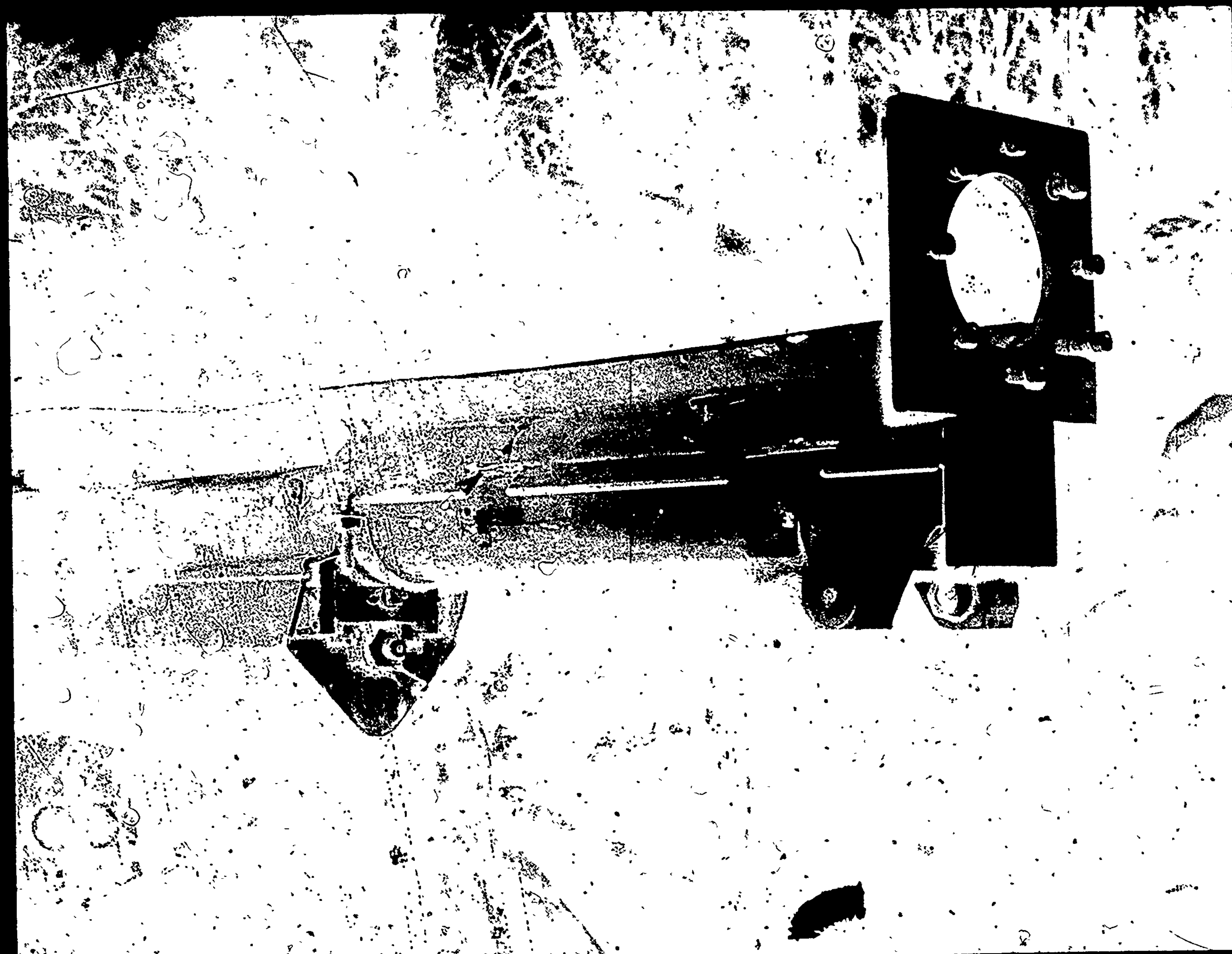
M-33920 Jan 1948 PICATINNY ARSENAL ORDNANCE DEPARTMENT

Mount for Launcher, Rocket, 4.5 Inch, with Launching Tube



M-33921 Jan 1948 PICATINNY ARSENAL ORDNANCE DEPARTMENT

(Mount for Launcher, Rocket, 4.5 Inch



M-33922 Jan 1948 PICATINNY ARSENAL ORDNANCE DEPARTMENT

Mount for Launcher, Rocket, 4.5 Inch